Fazio, A. R.

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Thesis

THE CONSTRUCTION AND VALIDATION OF A HIGH SCHOOL TEST EVALUATING UNDERSTANDING OF FIVE PRINCIPLES TAUGHT IN BIOLOGY

Submitted by

Alice Ruth Fazio

(B. S., Framingham Teachers College, 1948)

In partial fulfillment of the requirements
for the degree of Master of Education

1949

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Thesis Approved

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ACKNOWLEDGEMENTS

I am grateful to Dr. John Read for his guidance in the planning and conducting of this study. Thanks are also due to the pupils and teachers who cooperated with the administration of the tests.

TABLE OF CONTENTS

CHAPTER PAGE

I. STATEMENT OF THE PROBLEM 1

Scope and Limitations of the Problem 2

Definition of Terms 3

II. REVIEW OF THE RESEARCH 5

Changing Ideas in Science Teaching 5

Changing Ideas About Learning 6

Changing Ideas Concerning Testing 8

Advantages of Learning with Understanding 10

III. PROCEDURE OF THE STUDY 12

Population Tested 15

Administration of the Tests 16

Biological Fundamentals Test 17

IV. ANALYSIS OF THE DATA 28

Central Tendency and Variability 28

Individual Item Analysis 29

Coefficients of Correlation 33

Reliability of Test Scores 33

V. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH 35

SELECTED BIBLIOGRAPHY 38

LIST OF TABLES

TABLE PAGE

I. Results of the Total Test Scores. 28

II. Individual Item Analysis 32

CHAPTER I

THE PROBLEM

Definition of the Problem

The purpose of this thesis is to construct and validate a test that will measure, at the high school level, the degree to which the pupil has gained an understanding of certain basic principles in the field of biology. It is not the intent of the author to measure factual knowledge in this area.

Justification of the Problem

A source of stimulation in the selection of this problem was the great need of teachers for a knowledge of the extent to which pupils are grasping and applying the fundamental principles taught them. It is hoped that by revealing the degree to which the student is developing his understanding of these basic underlying principles that the classroom teacher will be aided in more effectively planning the course and in making the subject more real and functional in the lives of the students.

When and if this occurs, learning will take place on the highest of levels; namely, the pupil will develop understandings and will also increase his ability to apply and transfer his knowledge to new situations, in place of the present system whereby the pupil need often only be able to give back to the teacher words from the text or his notes, that are too often devoid of meaning, and involve merely rote memorization of factual material.

Regarding this matter of the development of understanding in students the Yearbook Committee[1] says,

> For many years educational theory has emphasized the importance of cultivating understanding through instruction. A similar statement cannot be made with regard to practice in classroom teaching. While there is plenty of evidence of a growing recognition of the role of understanding in the learning process, it is a fact that in our teaching we are still prone to pay lip-service to understandings as educational aims.
>
> It is equally important that we commit ourselves to the task of developing instruments that will function in the measurement of understandings. We cannot forever delude ourselves with the idea that pupils are really achieving understandings when the tests that are used measure exclusively proficiency in mechanical skills or command over assigned verbalizations.

Scope and Limitations of the Problem

In this study an achievement test designed for the measurement of understanding of five biological principles was constructed. The test consisted of thirty multiple choice questions and was administered to students in the biology classes of four high schools. The writer attempted the evaluation of the understanding of five principles taken from a master list of 300 major principles of biology as compiled by Martin.[2]

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[1] Forty-fifth Yearbook of the National Society for the Study of Education, Part I, The Measurement of Understanding. Chicago, Illinois: University of Chicago Press. 1946. pp. 321-22.

[2] William E. Martin, A Determination of the Principles of the Biological Sciences of Importance for General Education. Unpublished Doctor's Dissertation, University of Michigan, 1944.

Definition of Terms

The following terms recur frequently throughout and for the purpose of clarifying their meaning as they are used in this study they are here defined.

1. Biological sciences--those sciences which are directly concerned with living organisms and with the life processes and relationships of these organisms with the organic and inorganic elements of their environment.[1]

2. Principle--A principle of science is a comprehensive generalization which:

   a) Is stated positively and definitely.
   b) Is true with but rare exceptions within the limitations set up by the statement.
   c) Clearly states or implies a dynamic process or interaction.
   d) Is demonstrable experimentally.
   e) Is clearly not a part of a larger principle which can be definitely stated.
   f) Is not merely a definition or a description.
   g) Has wide application in the natural environment and is not ruled out by any of the above-mentioned.[2]

3. Understanding--the ability to see the immediate situation in terms

---

[1] William E. Martin, A Determination of the Principles of the Biological Sciences of Importance for General Education. Unpublished Doctor's Dissertation. University of Michigan. 1944.

[2] William E. Martin, "A Chronological Survey of Research Studies on Principles as Objectives of Instruction in Science," Science Education xxix, (February, 1945), pp. 45-52.

of the larger whole.[1]

4. Understanding of a principle--means that one can identify its appropriateness and usefulness in situations where it has not been seen or used previously.[2]

In this study a correlation of the marks the students obtained on the test with school marks and ratings from the California Mental Maturity Test was made.

It is the object of this research to construct a test that will be face-valid and reliable for use in measuring the degree of understanding attained by pupils of certain basic principles in the science of biology.

1/ William E. Martin, "A Chronological Survey of Research Studies on Principles as Objectives of Instruction in Science," Science Education, xxix (February, 1945), p. 28.

2/ Ibid. p. 41.

CHAPTER II

REVIEW OF RESEARCH

In reviewing past and present research the writer finds that much has been idealistically stated by those prominent in the educational field regarding the great importance of developing understandings as a primary objective in teaching.

The entire picture obtained is one that shows both teaching objectives and measurement devices to be in a state of flux or change with the emphasis in both being shifted from the acquisition of non-functional factual material to the teaching of understanding of basic principles. The following are some of the areas in which the change is taking place.

Changing Ideas in Science Teaching

Bernal[1/] emphasized in 1945 that the methods of science teaching have grown up in the past out of the need to provide training for science specialists: doctors, engineers, chemists, or geologists. As science teaching spread, these training purposes were minimized, but they were never abandoned.

In the new view, Berndl advocates that training in science serve two purposes:

> The first objective is to provide enough understanding of the place of science to enable the great majority that will not be

---

[1/] J. D. Bernal, "Science Teaching in General Education", Birkbeck College, University of London. Science Education, Vol. 29 (December, 1945), pp. 233-34.

> actively engaged in scientific persuits to collaborate intelligently with those who are, and to be able to criticize or appreciate the effect of science on society.
>
> The second objective is to give a practical understanding of scientific method sufficient to be applicable to the problems which a citizen has to face in his individual and social life.

Beauchamp's[1] study included a survey of the teaching method being used in 1932 in 40 high school biology courses. This research revealed that memorization of material and the assignment of problems which had little or no relation to the student's daily life were the dominant characteristics of the prevalent teaching method. Such a practice cannot be justified whether the course is intended for all students or only for those intending to specialize in the field of biology.

Changing Ideas About Learning

Hart[2] reports that more and more in educational circles evaluation is being used in place of measurement. Evaluation includes measurement but is broader in scope.

In tracing the development of achievement testing through the second and third decades of the present century he found the tests functioned primarily in the measurement of knowledge of facts and skills to the exclusion of the evaluation of almost all other aspects of learning.

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[1] Progressive Education Association, Commission on Secondary School Curriculum, *Science in General Education*, New York: D. Appleton-Century Company. 1938. p. 13.

[2] E. H. Hart, "Measuring Critical Thinking in a Science Course", *California Journal of Secondary Education*, Vol. 14. 1939. p. 334.

As the tests were widely used, the pupils naturally gave more attention to the memorization of detailed facts in order that they might achieve higher scores on the examinations. Thus the tests came to influence teaching and learning.

Tyler[1] pointed out that a common misconception implies that all learning is equally permanent or equally transient. During the past this author and others have collected evidence on what high school and college students forget. This evidence was obtained by retesting them at intervals after taking certain science courses. The results obtained in this study were for both high school and college students. Specific facts are largely forgotten. A year after taking the course the students recalled only about half of the facts which they knew when taking the course. Facts and principles of more general application, however, are not so largely forgotten, for one year later the students recalled 85% of them.

An investigation by Wert[2] convincingly showed that facts and principles that were general in nature were retained better than were specific facts. This conclusion was based upon results obtained from an experiment over a period of three years.

Zeigler[3] in 1942, discovered similar relationships.

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[1] Ralph W. Tyler, "Prevailing Misconceptions". Journal of Higher Education, Vol. 4 (June, 1933), p. 289.

[2] James E. Wert, "Twin Examination Assumptions", Journal of Higher Education, Vol. 8 (March, 1937). pp. 136-140.

[3] Robert T. Zeigler, "A Study of Fact Retention in General Science", Science Education, XXVI (February, 1942), pp. 83-84.

Changing Ideas Concerning Testing

In a research paper written by Johnson[1] the author notes that an examination of the more commonly used standardized tests or the informal objective tests of the teacher reveals that they are largely concerned with the measurement of the acquisition of more or less detailed information.

Teachers frequently object to including questions in an examination that have not been previously answered in class or in other sources of materials of instruction. This is further evidence of the fact that emphasis is placed mainly upon the memorization of information. To test the student's ability to apply and transfer his knowledge, it is necessary to introduce situations or problems to which he has not been previously exposed.

The Forty-Fifth Yearbook[2] states that the techniques for measuring factual knowledge are fairly well worked out, and these techniques are known to teachers and are fairly well administered by them in the classroom. It is the opinion of this committee that due to the ease with which the teacher uses this type of testing a great many teachers feel that because they have measured the acquisition of factual knowledge and skills that they have measured all that needs to be measured. In these circumstances--and they are by no means rare--there is small likelihood that understandings will be evaluated.

In 1942 Davis[3] drew attention to the existence of a changing point of view in evaluation or testing. He pointed out that many new types of tests

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[1] Palmer O. Johnson, "The Measurement of Outcomes of Instruction Other Than Information", School Science and Mathematics, 1934. pp. 26-33.

[2] William A. Brownell, "Purpose and Scope of the Yearbook", National Society for the Study of Education, Forty-Fifth Yearbook, Part I. 1946. p. 2.

[3] Ira C. Davis, "Trends in Science Teaching", School Science and Mathematics 1942. p. 453.

are being used. The shift is from pure information items to questions which attempt to get at outcomes, applications, understandings, appreciations, attitudes, and methods.

The following two points were made by Heil[1] and are worthy of note in connection with the use of evaluative devices. First, the particular devices used for evaluating a student's understanding in science should correspond to the ideas dealt with directly in day-by-day instruction. Important objectives must be "taught for" directly. They are not by-products of instruction.

The second point concerning the use of evaluative devices involves their construction. The alternative responses of an objective test should be planned in such a way that "wrong" responses are as revealing as are right ones. This means that the teacher has the responsibility of indicating both to himself and to his students the basis of failure in achieving understanding.

Learning With Understanding

Functional understanding of principles is considered to be an important objective of science teaching. "They provide focal points for the organization of instructional material and they constitute the generalizations toward the formulation of which most work in science is directed."[2]

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[1] Louis M. Heil (Chairman), "The Measurement of Understanding." National Society for the Study of Education, Forty-Fifth Yearbook, Part I. p. 136.

[2] "Science Education in American Schools", National Society for the Study of Education, Forty-Sixth Yearbook, Part I. Chicago, Illinois: University of Chicago Press. 1946. p. 31.

Every teacher knows that in some cases the learning stops with a certain amount of memorizing of facts. It is well established that "facts so learned are soon forgotten". "On the other hand, if functional understanding of principles is attained, the ability to use them and to apply them is retained remarkably well."[1/]

Advantages of Learning With Understanding[2/]

1. Meaningful learning is economical learning--experiments have proven that a student learns with increasing rapidity that which he has an understanding of.
2. Learning with understanding is relatively permanent.
3. The effects of learning with understanding are cumulative. This statement means that understanding facilitates the learning not only of the immediate tasks but of subsequent tasks as well.
4. Understanding results in learning with functional value. This statement means that learning with understanding is transferable, that is, the child can apply what he has learned to new and different situations outside of the classroom.

At the present time most teachers have adopted the "new type" or objective forms having been convinced for the most part that the essay test is unreliable and has many weaknesses. They soon experienced difficulty in

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1/ "Science Education in American Schools", National Society for the Study of Education, Forty-Sixth Yearbook, Part I. Chicago, Illinois: University of Chicago Press. 1946. p. 185.

2/ "The Measurement of Understanding", National Society for the Study of Education, Forty-Fifth Yearbook, Part I. Chicago, Illinois: University of Chicago Press, 1946. pp. 14-16.

framing "thought questions" in the pattern of these test forms. The result of this is that objective testing is almost exclusively fact-testing. "The new types of test items can be utilized to measure meaningful outcomes and they should be so used!"[1]

It is the hope of this writer and the major aim of this thesis to construct a test that will show the possibility of objective testing in this area of understandings.

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[1] "The Measurement of Understanding", National Society for the Study of Education, Forty-Fifth Yearbook, Part I. Chicago, Illinois: University of Chicago Press. 1946. p. 19.

CHAPTER III

PROCEDURE USED IN THE STUDY

A survey of the related research reveals that the development of tests for the specific purpose of measuring aspects of learning such as understandings is at the present still in the experimental stage. The pencil and paper test presented in this thesis represents an attempt on the part of the author to measure the pupil's understanding of five fundamental principles in the field of biology.

The Planning of the Study

The first step in the organization of this test was the compiling of a list of fifteen principles selected by this author from Martin's[1] list of 300 major biological principles. The fifteen principles chosen were believed to be, in the opinion of the members of a Seminar in Science Teaching,[2] likely to be covered in most biology courses at the secondary level.

The following list of principles was presented to the teachers of the classes tested. The teachers were instructed to place a check mark beside

---

[1] Edgar W. Martin, A Determination of the Principles of Biological Sciences of Importance for General Education. Unpublished Doctor's Dissertation, University of Michigan. 1944.

[2] Dr. John Read, Instructor, Seminar in Science Teaching, School of Education, Boston University, Boston, Massachusetts.

five of these principles that they felt they had most adequately covered in their instruction.

1. Cells are organized into tissues, tissues into organs, and organs into systems, the better to carry on the functions of a complex organism.
2. All life comes from preceding life.
3. The ultimate source of the energy of all living things is sunlight.
4. The smallest unit of living material capable of existing independently and of maintaining itself is the unit called the cell.
5. Micro-organisms are the immediate cause of some diseases.
6. From the lower to the higher forms of life, there is an increasing complexity of structure, and this is accompanied by a progressive increase in division of labor.
7. Digestion in plants and animals is carried on by enzymes, or organic catalysts, which are made by the organisms themselves and which take part in and speed up chemical reactions but do not undergo any permanent chemical change.
8. Food, oxygen, certain optimal conditions of temperature, moisture, and light, are essential to the life of most living things.
9. Animals and plants are not distributed uniformly or at random over the surface of the earth, but are found in definite zones.
10. Carbon dioxide set free during the respiration of both plants and animals is absorbed by plants and used as a raw material of photosynthesis.

11. All the higher forms of terrestrial life are dependent either directly or indirectly on the soil bacteria for their nitrogen supply.
12. Every cell consists essentially of a mass of protoplasm which is usually differentiated into a central portion, the nucleus, and an outer portion, the cytoplasm.
13. Throughout the life of every organism there is a building up and a tearing down of protoplasm with constant transformation of energy.
14. Energy and matter are not created or destroyed in the reactions associated with the life processes, but are passed on from organism to organism in endless succession.
15. All living organisms (except viruses and bacteriophage) carry on the common life processes, reproduction, growth, nutrition, excretion, respiration, and irritability.

Four principles were unanimously selected from the above list by all of the teachers involved. General agreement was lacking in the selection of a fifth principle, so the list was submitted to members of the Seminar in Science Teaching (previously mentioned) and a fifth principle was selected.

The following list comprises the five principles selected by the teachers and members of the Seminar and upon which the author based her test.

1. The smallest unit of living material capable of existing independently and of maintaining itself is the unit called the cell.
2. Digestion in plants and animals is carried on by enzymes, or organic catalysts, which are made by the organisms themselves and

which take part in and speed up chemical reactions but do not undergo any permanent chemical change themselves.

3. Every cell consists essentially of a mass of protoplasm which is usually differentiated into a central portion, the nucleus, and an outer portion, the cytoplasm.
4. Cells are organized into tissues, tissues into organs, and organs into systems, the better to carry on the functions of complex organisms.
5. Carbon dioxide set free during the respiration of both plants and animals is absorbed by the plants and used as a raw material of photosynthesis.

The second step involved the editing of the test items. After a thorough review of the research, multiple choice items were constructed; this particular type of objective test item lends itself well to the measurement of the higher mental processes such as understanding. Five alternative responses were given in each question. The test was limited to thirty questions and was given in a 45-minute high school period.

The third step involved the administration of the tests.

The fourth step consisted of a statistical analysis of the results.

The Population Sample for the Experiment

The test was given to 313 pupils who were students in the biology classes of four high schools. Three of these high schools were in suburban towns while the fourth was located in a large city.

Administration of the Test

The tests were administered to the entire sample by the classroom teachers. The pupils were instructed to read each question through very carefully and they were told that the time allotted to them would be ample to allow them to complete the test. Intelligence test scores along with the teachers' final mark of each pupil were obtained through the cooperation of the school systems involved. The writer corrected and scored all tests.

BIOLOGICAL FUNDAMENTALS TEST

Directions: Read each question through carefully. Take enough time to consider each of the five choices in relation to the question. Place a check mark directly beside the letter of the answer that you believe to be the correct one.

The following is a sample question.

A horse always has

____a) a rider
_✓_b) hoofs
____c) saddle
____d) stirrup
____e) reins

In this case b is the correct answer.

There is only one correct answer to each question in this test.

1. If plants suddenly ceased to absorb carbon dioxide set free during animal respiration and no longer were active in performing the process of photosynthesis which of the following would occur?

____a) Life in its various forms would remain unmodified.
____b) Sources of food other than the green plant would be used.
____c) There would be no animals on the earth.
____d) Adoptive modifications would take place in animals.
____e) Plant life alone would be destroyed; all other organisms would not be affected.

2. To be successful in building a balanced aquarium the Most important thing to keep in mind would be

____a) To have an adequate amount of pebbles, rocks, shells, and plant and animal food.

____b) Aquaria need light for healthy plant growth.

____c) To allow the plants to become adjusted to their new home before putting in the animals.

____d) Not to have more than two fishes three inches long for each gallon of water.

____e) The dependence of the plants upon the animals for a supply of carbon dioxide and of the animals on the plants for their supply of oxygen.

3. By the action of light on the pigment, chlorphyll, protoplasm is enabled to

____a) Manufacture starch from carbon dioxide and water.

____b) Move or bend the plant towards the source of light.

____c) Utilize foods and liberate energy from them to do work.

____d) Carry on growth and reproduction.

____e) absorb minerals from the soil.

4. The maintenance of life in animals and non green plants is Wholly dependent on the

____a) Power of automatic cell division and reproduction.

____b) Food manufactured by green cells.

____c) Power of response to external stimuli.

____d) ability to make successful environmental adjustments.

____e) Powers of growth, waste, and repair.

5. Certain properties of protoplasm make possible certain reactions on the part of an organism. For example when a person touches his finger to a hot stove and immediately withdraws it which of the following factors were necessary to Complete the reaction?

____a) The presence of an external stimulus.

____b) A sensitivity of the skin to the stimulus.

____c) Liberation of energy which will enable the required muscles to contract.

____d) Stimulation, conduction of the stimulus to a nerve center, followed by the contraction of the required muscles.

____e) Contractility, which is the power of contraction and relaxation that is common to the substance of every cell.

6. The Prime purpose of all digestion is to

____a) Transform food into a form which can be readily utilized by the organism for growth, storage, energy and repair.

____b) Liquify all food so that it may readily pass thru the alimentary canal.

____c) Provide plants and animals with sufficient energy to enable them to perform work.

____d) Break down fats into fatty acids and glycerols and proteins into amino acids.

____e) Permit the absorption through intestinal wall into the blood stream of all food taken in.

7. Cells grow, tend to reach a maximum size, and when this size has been reached they automatically divide. One of the following constitutes the Main reason for this division

____a) to keep the cells of their proper size and to maintain the structure of the organism.

____b) To allow for the division of labor among the cells.

____c) To better carry on the numerous functions of the entire cell.

____d) To allow for the development of the various types of cells such as nerve cells, muscle cells, glandular cells, etc.

____e) To produce a continuous stream of new cells.

8. A collection of cells alike in structure and performing the same function would be called a tissue. Which of the following would be classed as tissue.

____a) Esophagus.

____b) Kidney.

____c) Muscle~~s~~.

____d) Intestine~~s~~.

____e) Lung~~s~~.

9. The control of growth to a given size characteristic of a given kind of animal is basically a matter of the control of

____a) Cell division,

____b) Cell size.

____c) Shape of the cell.

____d) Flexibility of the cell wall.

____e) The amount of food available during the growing process.

10. Systems such as the digestive or circulatory system, as they are found in animals and plants are best described as consisting of

____a) A single cell serving many functions.

____b) A tissue composed of a mass of like cells.

____c) A group of organs which act together to perform a special function.

____d) Two or more tissues grouped together to perform a special function.

____e) An aggregation of cells that may be differentiated into connective cells, nerve cells, and muscle cells.

11. A single celled animal is capable of performing certain functions in a rather crude manner. Man can perform these same functions in an extremely efficient manner because he

____a) Is larger and stronger and possesses greater physical and mental capacities.

____b) Possesses a great many cells instead of just a single cell.

____c) Has increased powers of locomotion and greater response to external stimuli.

____d) Has a higher type of cell organization that enables him to better carry on the functions of a complex organism.

____e) Possesses an exoskeleton and a highly complex nervous system.

12. Certain structures in both plants and animals have certain functions to perform. The function of a root of a plant is to absorb certain materials from the earth. Knowing this much about a root you would classify it as

____a) A system.

____b) An aggregation of glandular cells.

____c) An organ.

____d) Areolar connective tissue.

____e) Epithelial tissue.

13. Contrary to what one would expect the amount of an enzyme present in an organism is not very large in comparison to the amount of food on which it acts. Select the Most Logical explanation that accounts for this

____a) Enzymes speed up the process of digestion but do not undergo any permanent change themselves. They are not lost in the process of reaction.

____b) Each enzyme is very specific in that it will produce its effect on only one type of food.

____c) If the conditions of temperature are correct for a particular enzyme its effectiveness is greatly increased.

____d) Enzymes have the ability to readily combine and mix with food, therefore only small quantities of them are needed.

____e) Enzymes are highly concentrated and because of this a small amount is capable of dissolving and breaking down large amounts of food.

14. Select the reason you think Best explains why enzymes are so vital to the digestive system of all plants and animals

____a) They successfully decrease the rate of digestion and thus permit longer and more complete utilization of the food.

____b) Food in the form in which it exists in nature cannot be used directly by living organisms.

____c) They aid in the mastication of food and in peristalsis.

____d) They break down certain foods usually those that are too complex for the organism to absorb and assimilate.

____e) They greatly increase the caloric value of the food as it passes through the alimentary canal.

15. Which of the following would be classed as living protoplasm?

____a) Wood.

____b) Lining of the intestines.

____c) Outside layer of your skin.

____d) Bones.

____e) Hair.

16. From which of the following sources do all digestive enzymes originate?

____a) They are present in and are active constituents of food.

____b) They are present in food but are unable to function until they have been masticated and mixed with the saliva.

____c) They are manufactured within the bodies of all plants and animals.

____d) They are present in certain foods only, and if the diet is not correctly balanced they are likely to be lacking.

____e) They are produced by a single gland found in the bodies of all plants and animals.

17. Cells of various kinds such as muscle cells, glandular cells, etc., would

____a) Be unlike in their structure.

____b) Differ only in shape and size.

____c) Have similar shapes but are very unlike in basic structure.

____d) Have similarity in size, shape and function and would differ only in their location within the body.

____e) Would possess marked similarity in the structure of the cell.

18. Pepsin is the name of a substance found in the stomach of man that aids him in digesting his food. Which of the following gives the Most Complete description of this reaction of pepsin?

____a) Takes part in and speeds up the process of digestion.
____b) Works best in an acid medium.
____c) Combines with the food forming a mixture of almost liquid consistency.
____d) Enters into and is changed by this reaction when there is an excess of hydrochloric acid present in the system.
____e) Speeds up the process of digestion but is not permanently changed in in any way itself,

19. In the protoplasm of the cells of green plants we find a number of little green colored bodies known as chloroplasts. These chloroplasts by means of energy received from the sun are able to

____a) Absorb minerals from the soil.
____b) Grow and reproduce themselves.
____c) Manufacture starch out of certain raw materials.
____d) Evaporate water from the leaves.
____e) Take in nitrogen in the form of nitrates from the soil.

20. Animals of different sizes vary in size because

____a) The cells of some animals are much larger than the cells of other animals.
____b) Some animals have more cells than others.
____c) Some animals have larger exoskeletons.
____d) The surface area of the body is greater in some animals.
____e) Their cells differ widely in shape and structure.

21. The action of an enzyme such as lipase that serves in the breaking down of fats would Best be described as being

____a) Retarding in nature - in that it slows down the process of digestion.

____b) Liquifying in nature - in that it mixes with the fat and breaks it down into fatty acids and glycerols.

____c) Dissolving in nature - in that it dissolves the fats so that they can be absorbed through the intestinal wall.

____d) Hastening in nature - in that it speeds up the breaking down of fats into simpler forms.

____e) Combining in nature in that it serves to mix the fat with itself and other digestive enzymes present.

22. In the so-called "higher animals" functions such as digestion, circulation, respiration, etc. are assigned to a certain organ or group of organs. This division of labor is not present in "lower animals" and because of this

____a) They are enabled to perform certain functions with increased efficiency.

____b) They are capable of functioning with greater speed.

____c) They do not perform with a degree of efficiency equal to that of the higher animals.

____d) They are not capable of carrying on all of the vital functions.

____e) They function more slowly but just as efficiently as the higher animals.

23. The smallest units of living material that are capable of independent existence and maintenance are

____a) Nuclei.

____b) Chromosomes.

____c) Cells.

____d) Golgi bodies.

____e) Centrosomes.

24. Green plants turn toward the source of light while earthworms are repelled by light. Both of these organisms are displaying which of the following characteristics of protoplasm.

____a) Contraction.

____b) Irritability.

____c) Conductivity.

____d) Metabolism.

____e) Spontaniety.

25. In looking carefully at the organ of a plant called a leaf we find that the materials of which it is composed do not appear to be everywhere the same. If we were to examine many different parts of this leaf under a microscope we would find

____a) One part very different from another in structure and appearance.

____b) All parts to be made up of a complex system of veins.

____c) All parts made up of units that are alike in shape only.

____d) All of the parts made up of tiny box like units of various sizes and shapes.

____e) All parts made up of units of similar shapes and size.

26. The Amoeba is a very simple one-celled animal. From your knowledge of cells which of the following would this single celled animal be incapable of performing

____a) Digestion.

____b) Excretion.

____c) Reproduction.

____d) Increasing the size of the individual by the formation of new cells.

____e) Movement.

27. Each organ in the body of a plant or animal has its function. At the same time it should be remembered that each organ

____a) Functions independently of all other organs.

____b) Is dependent upon the proper workings of all the other organs of the body

____c) Is specific in the function and entirely unrelated in any way to other organs.

____d) Will continue to function regardless of the condition of all other organs

____e) Is dependent only upon the heart for the continuence of its functions.

28. Plants and animals exhibit many of the same characteristics and on the other hand they also show many differences in structure and behavior. Those things which they have in common may be Best accounted for by which of the following?

____a) Present in the bodies of both plants and animals is a substance called protoplasm.

____b) Many similar organs are found in both plants and animals.

____c) Both require oxygen and water to carry on life processes.

____d) Sunlight is the source of energy for all plants and animals.

____e) The similarities are a result of living under the same environmental conditions.

29. Choose from the following the definitions which to your mind most Correctly and Completely describes typical plant and animal cells.

____a) A mass of protoplasm surrounded by a cell wall.

____b) Undifferentiated protoplasm encased in a cell wall or membrane.

____c) A mass of protoplasm, surrounded by a cell wall or membrane and divided into a nucleus and an outer portion called a cytóplasm.

____d) Protoplasm consisting of a nucleus and a cell wall.

____e) A single bit of protoplasm with its cell wall.

30. A wound in an animal skin is replaced by new tissue which grows out of the surrounding skin. The organism in this example would be showing which of the following properties of protoplasm?

____a) Sensitivity.

____b) Growth.

____c) Reproduction.

____d) Irritability.

____e) Spontaniety.

CHAPTER IV

ANALYSIS OF DATA

Introduction

The evaluation of this test includes some general measures of central tendency and variability, individual item analysis for difficulty and discrimination indices, correlation of the test scores with scores on the California Mental Maturity Test and the term marks as evaluated by the teachers, and a determination of estimated reliability.

Statistics on Central Tendency and Variability

The summarized data obtained from the original administration of the test include the arithmetic mean, standard deviation, range, highest possible score, and the number of pupils for the whole test.

TABLE I

Results of the Total Test Scores

Mean in percents	Standard Deviation	Range in percents	Highest Possible Score	Number of Pupils
55.607	6.07	17-93 of 77	100	313

The scores on the test were translated into scores which represented the percentage scores when the test was scored on the basis of 3 1/3 scale points for each item.

Because the teachers were promised that scores on the test would be returned to them, the whole calculation has been carried out on this basis.

A copy of the statistical material is available to the teachers.

Individual Item Analysis

The item analysis is for the purpose of securing a difficulty index and a discrimination index for each test item. The necessary data for the analysis was obtained by administering the test to 313 pupils in four high schools. The upper 27 per cent and the lower 27 per cent of the scores were used as suggested by Davis.[1]

A tally was made of both the high and low papers to determine the number who answered each item correctly and then to determine the number who answered each item incorrectly. A tally was also made to determine the number who reached the item in each group.

In order to correct for guessing the necessary percentages with which to enter the Item Analysis Chart[2] the following formulas were used:

$$P_H = \frac{R_H - \frac{W_H}{K-1}}{N_H - NR_H}$$

$$P_L = \frac{R_L - \frac{W_L}{K-1}}{N_L - NR_L}$$

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[1] Frederick B. Davis, *Item Analysis Data--Their Computation, Interpretations and Use in Test Construction*. Cambridge, Mass.: Harvard University, Graduate School of Education.

[2] *Ibid*.

where:

R_H = number of testees in the highest 27 percent that answered the item correctly.

W_H = number of testees in the highest 27 percent that answered the item incorrectly.

R_L = number of testees in the lowest 27 percent who answered the item correctly.

W_L = number of testees in the lowest 27 percent who answered the item incorrectly.

N_H = number of testees in the highest 27 percent of the sample.

NR_H = number who did not reach the item in the highest group.

NR_L = number who did not reach the item in the lowest group.

K = number of choices

The table for the individual item analysis gives the test item number, the per cent of right and wrong answers with the highest group of 27 per cent, the per cent of right and wrong answers with the lowest 27 per cent, the corrected percentage for each group, the discrimination index and the difficulty index for each item.

The discrimination index expresses the degree to which a test item distinguishes between pupils of limited ability and those of greater ability. Davis1/ states that any item with a discrimination index of over 20 is significant, and includes a table to show relationship between his

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1/ Frederick B. Davis, Item Analysis Data--Their Computation, Interpretations and Use in Test Construction. Cambridge, Mass.: Harvard University, Graduate School of Education.

indices and the critical ratio which is often used. The indices in the chart range from 0 to 100.

The difficulty index is a means of comparing the difficulty of a test item with other items in the same test. The index is expressed in numbers from 1 to 99 beginning with the most difficult. Items with indices of 50 are most valuable, while those near 1 and 99 are useless. The usual practice is to include items with a wide range of difficulty.

Any negative indices found in the following tables when the original percentages used to enter the Item Analysis Chart1/ were corrected for guessing and for failure of the pupil to reach the item. They may be interpreted as zero items and are not significant.

1/ Frederick B. Davis, Item Analysis Data--Their Computation, Interpretations and Use in Test Construction. Cambridge, Mass.: Harvard University, Graduate School of Education.

TABLE II

Individual Item Analysis

Test Item	Highest 27% R	Highest 27% W	Lowest 27% R	Lowest 27% W	Per Cent High	Per Cent Low	Discrimination Index	Difficulty Index
1	80	5	57	28	94	67	27	68
2	82	3	54	31	96	63	34	68
3	62	23	28	57	72	32	25	51
4	58	27	20	65	68	23	29	48
* 5	77	8	70	15	90	80	11	72
6	73	12	38	47	83	44	28	58
7	37	48	8	77	43	1	52	34
8	76	9	49	36	87	57	24	63
9	60	25	29	56	70	34	23	51
10	80	5	47	38	94	55	35	64
11	71	14	39	46	81	45	25	58
12	62	23	30	55	72	35	23	52
13	58	27	25	60	66	29	23	49
*14	48	37	30	55	56	35	12	48
15	73	12	41	44	83	48	25	59
16	76	9	35	50	87	41	34	58
17	35	50	13	72	41	1	51	33
*18	60	25	22	63	71	47	16	55
19	81	4	40	45	95	47	44	62
20	73	12	24	61	83	28	39	53
*21	30	55	20	65	35	23	8	39
22	72	13	43	42	82	50	23	59
23	80	5	35	50	94	41	43	60
24	76	9	50	35	87	58	24	63
25	46	39	21	64	54	24	20	44
26	78	7	32	53	91	37	42	58
27	76	9	37	48	87	43	32	59
28	37	48	11	74	43	1	52	34
*29	76	9	56	29	87	65	19	66
30	45	40	18	67	52	20	22	42

* The starred items appearing in the above table are not statistically significant.

With the paragraph on interpretation preceding the table it is easy to select items with sufficient discrimination power to be included in a refined test. Twenty-five items out of thirty have indices of over 20 and are therefore significant. The range of difficulty is from 72 to 33, from easiest to most difficult. All of the items had indices between 26 and 75.

Coefficient of Correlation

The coefficient of correlation between the original test scores and the intelligence quotients was .46 and between the test scores and the term marks assigned to the pupils by their teachers was .54.

Reliability

One method for obtaining an estimate of the coefficient of reliability is the "Footrule" coefficient.[1] The only necessary data are the mean and standard deviation of the test scores and the number of test items.

The formula follows:

$$r_{tt} = \frac{n}{n-1} \times \frac{\sigma t^2 - n\bar{p}\bar{q}}{\sigma t^2}$$

Where $\bar{p} = \frac{M_t}{n}$ $\quad \bar{q} = 1.00 - p$

M_t = arithmetic mean of the test scores.

σt = standard deviation of the test scores.

n = number of test items.

The estimated coefficient of reliability thus obtained is 0.33.

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[1] Green, Jorgenson, and Gerberich, Measurement and Evaluation in the Secondary School. p. 591.

It would be possible to improve the reliability of this test by lengthening it.

The author wishes to restate that the main purpose of this test was to produce items with high discrimination indices.

CHAPTER V

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Following a careful review of the literature pertaining to science teaching, all of which revealed a need for the development of evaluative instruments that would measure aspects of learning above and beyond memorized factual material, this author endeavored to construct a test that would measure the pupil's understanding of five basic principles in the field of biology.

The test was administered to 313 students in four high schools in the New England area. The sampling obtained was representative of three suburban towns and one large city system.

The ratings by the individual classroom teachers along with scores on the California Mental Maturity test were obtained and were used in a correlation study with the writer's test.

Each item in the test was statistically analyzed for its critical ratio and index of ease.

An analysis of the data made evident the following conclusions.

1. An understanding of the five principles measured had not been obtained by all of the 313 pupils tested.
2. There is not a high relationship between intelligence and scores on this test.
3. There is not a high relationship between teacher's marks and scores on this test.

4. Twenty-five items out of thirty were valid as determined by an item analysis.
5. Scores on this test offer further proof that the emphasis in teaching is still placed mainly on the memorization of factual material.

The low correlations between the writer's test and intelligence and between the writer's test and the teachers' marks should not be overlooked. It is known from research that tests of this type do not correlate highly with school marks and intelligence ratings.

The sole purpose of this test was to measure understanding of certain basic principles in biology. That pupils acquire an understanding of these principles is ranked as one of the most important objectives of biology teachers. However, this objective has only been partially realized and in many cases is still being totally neglected in classroom instruction.

It should also be noted that four out of the five questions that had discrimination indices of below 20 were all based upon the following principle:

Digestion in plants and animals is carried on by enzymes, or organic catalysts, which are made by the organisms themselves and which take part in and speed up the chemical reactions but do not undergo any permanent chemical change themselves.

It is remarkable that the four items that were not discriminatory were all based on this same principle. This principle is apparently not understood by most of the testees despite the fact that the teachers were willing to have it included in the test.

A revision of the test that would involve lengthening the test and omitting the items that were not statistically significant would greatly increase the reliability.

Suggestions for Further Research

1. The development of similar tests for the measurement of other biological principles should be undertaken.
2. Other procedures should be developed for exposing aspects of understanding which are not explored by written tests.
3. A revision of the test should be made that would involve:
    a. arrangement of items in order of relative difficulty according to index of ease
    b. omission of items that are not statistically significant.

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